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Conservation status of Amphibians of Argentina: An update and evaluation of national assessments

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***Abstract.*—We present a review on the conservation status of the 177 species and subspecies of amphibians of Argentina and compare the first national assessment, conducted in 2000, with the most recent one, from 2012, to determine changes in conservation status over time. We also evaluate the degree of taxonomic and geographic non-randomness in extinction risk among these taxa. The present study shows an improvement in the knowledge of amphibian diversity in Argentina, but also increasing evidence of population declines and species absences. Twenty-two species showed a genuine increase in threat status between national assessments, and habitat loss and/or degradation, chytrid fungus infection, and introduction of invasive species have been reported as the main threats. Randomization tests showed families Telmatobiidae and Batrachylidae to be over-threatened and Hylidae and Leptodactylidae to be significantly under-threatened. Also, four ecoregions were shown to be significantly over-threatened (Patagonian Steepe, Patagonian Woodlands, Puna, and Yungas Forests). This evaluation help to identify groups of species that face similar suites and intensities of threat as a result of their overlapping geographical distributions and shared biological susceptibility as a result of their evolutionary history. We consider that our results highlight patterns and trends to alert policymakers and to guide priority actions.**

Keywords. Batrachylidae, diversity, ecoregions, Hylidae, Leptodactylidae, threats

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Introduction

The widespread loss of biological diversity on a global scale poses a challenge demanding effective methods to assess the threat status of the biodiversity at a range of spatial scales (Mace et al. 2008). Global, regional, and/or local assessments of the status of species according to their extinction risk are important tools for guiding the development of conservation planning policies and regulations. Since most conservation actions are based on the threat category assigned to the species, the implementation of more efficient public policies and the improvement of public awareness may depend on reliable species information and assessments (Hoffmann et al. 2010).

Argentina harbors the tenth largest amphibian fauna among the 40 countries included in the Neotropical Realm. The Argentine amphibian fauna is also highly endemic, being among the twenty countries in the world in which 30% of its amphibian species are endemic (Bolaños et al. 2008; Lavilla and Heatwole 2010). Like in most Neotropical countries, there are major gaps of information on the amphibian species of Argentina including systematic, genetic, range size, natural history, and ecology (Lavilla and Heatwole 2010). The usual barriers faced to accurately assess the threat status of amphibians in such countries are the many remote or unexplored regions coupled with relatively few scientific experts to detect, identify, and study species and/or populations, and the limited resources available to evaluate them (Becker and Loyola 2008; Brito 2008). Although challenging, the sum of individual efforts by amphibian researchers allowed, the development of the first national Red List of amphibians of Argentina in 2000, using a locally designed categorization method (Lavilla et al. 2000). Other contributions later summarized and updated the information on Argentinean amphibian diversity,

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geographic distribution, and description of the principal threats (Lavilla and Cei 2001; Lavilla et al. 2002; Lavilla and Heatwole 2010).

Given the substantial increase in the rate of amphibian species description (Köhler et al. 2008), continual updating of existing conservation assessments is necessary in order to properly maintain that assesment's value (Stuart 2007). A status review requires the compilation of new information from new species descriptions, new taxonomic arrangements, and new evidence or research, and in most cases it is necessary to reassess the consensus of several experts about conservation status (Lukey et al. 2010). To accomplish this task, a new assessment of the conservation status of the amphibians of Argentina was published in 2012. The updated assessment shows an improvement in the knowledge of amphibian diversity in Argentina, but also increasing evidence of population declines and species absences (Vaira et al. 2012).

Nevertheless, none of the existing assessments or updates on the diversity and conservation status of Argentinean amphibians evaluate whether phylogenetically related species or those sharing similar distributional ranges face similar kinds of threats. Taxonomic and geographic selectivity in threats has been observed in some vertebrates, consisting of non-random distributions of the extinction risk of species among families or regions (Russell et al. 1998). Species have different probabilities of extinction depending on intrinsic factors like body size, population size, and genetic variability (Sodhi et al. 2008). Moreover, the probability of extinction rely also on external factors such as human disturbance, disease, habitat loss, and other threatening processes, as well as on the interaction between such extrinsic and intrinsic factors (Bennett and Owens 1997), and even stochastic events associated with small population sizes (Schaffer 1981). It is therefore possible that species that share some of these factors will have similar levels of threats. Thus, an evaluation of taxonomic and geographic patterns in the threat status of amphibians of Argentina could be used to focus conservation practices on entire clades or particular biogeographical regions rather than on individual species (Mace et al. 2003; Bielby et al. 2006; Corey and Waite 2008).

Given the reported improvement in the knowledge of amphibian diversity in Argentina (Vaira et al. 2012), coupled with changes in the conservation status and the intensity of threatening processes, prompted us to analyze changes in species' conservation status between the first comprehensive Argentinean conservation assessment (Lavilla et al. 2000) and the most recent one (Vaira et al. 2012). We are interested to know if reported changes are attributable to genuine improvement or deterioration of their conservation status or attributable to improved knowledge on taxonomy, ecology or distribution of the species. We also evaluate the degree of non-randomness in threat status of the species by taxonomy and geographic distribution to analyze whether threat status was randomly distributed across taxonomic families or regions.

Materials and Methods

The method used to categorize threatened species in Argentina was originally proposed by Lavilla et al. (2000), adapted from the method of Reca et al. (1994). More recently, Giraudo et al. (2012) reviewed the method with the aim to improve consistency and provide guidance on the assessment process. The categories are: Insufficiently Known (IC), Not Threatened (NA), Vulnerable (VU), Threatened (AM), and Endangered (EP).

We evaluated the changes in the conservation categories of the different taxa between the two assessments. A status change due to reported increase or decrease of threats was considered a "genuine" change. Those changes attributable to improved knowledge of both geographic distribution and taxonomy of the taxa were considered as "non-genuine" status changes (adapted from Hoffmann et al. 2010).

We followed the analytical methods proposed by Bielby et al. (2006) to analyze whether threat status was randomly distributed across taxonomic families and regions. We combined the categories VU, AM, and EP as Threatened and retained category NA as Not-threatened. The taxa in the IC category were omitted from the analysis, in order to remove the effects of non-random lack of knowledge for conservation status (Bielby et al. 2006). We then constructed two data sets ordering threat categories by taxonomic family or region. We assigned taxa range distributions to regions following the ecoregion classification scheme described in Lavilla and Heatwole (2010).

For each of the data sets, we first conducted a chi-square test to test for deviation from the null expectation that threatened taxa are distributed randomly among families or ecoregions. When non-random extinction risk was detected, we conducted further analyses to determine which families or ecoregions deviated from the expected level of threat. We did this by using a binomial test to calculate the smallest family size necessary to detect a significant deviation from the observed proportion of threatened taxa and excluded the families represented by an insufficient number of taxa.

For taxa in the remaining families, we generated a null frequency distribution of the number of threatened species from 10,000 unconstrained randomizations, by randomly assigning the categories to all remaining taxa. We then compared the actual number of threatened taxa in the datasets with the null frequency distribution. The null hypothesis (extinction risk is taxonomically and geographically random) was rejected if this number fell in the 2.5% at either tail of the distribution.

Table 1. Taxonomic arrangements of amphibians of Argentina not included in the list of the 2012 national assessment by Vaira et al. (2012).

Taxon name listed in Vaira et al. 2012	Changed to	Source
Alsodes gargola gargola	*Alsodes gargola*	Blotto et al. 2013
Alsodes gargola neuquensis	*Alsodes neuquensis*	Blotto et al. 2013
Not listed	*Elachistocleis haroi*	Pereyra et al. 2013
Not listed	*Oreobates berdemenos*	Pereyra et al. 2014
Pseudis limellus	*Lysapsus limellum*	Garda et al. 2010
Somuncuria somuncurensis	*Pleurodema somuncurense*	Faivovich et al. 2012
Leptodactylus diptyx	*Adenomera diptyx*	Pyron and Wiens 2011

Results

Update and summary of the conservation status of the amphibians of Argentina

Based on taxonomic changes and the description of two new species since 2012, updated list of amphibians of Argentina consists of a total of 17 families, 42 genera, and 177 species and subspecies (Tables 1 and 2).

Twenty taxa registered a "genuine" status change in its threat categories when comparing the 2000 Argentinean conservation assessment with the 2012 list, (Table 2). Most status changes represent an increase in the threat categories for the taxa due to: population decline (65%), habitat deterioration (25% of taxa), invasive species (10% of taxa), or by infection caused by the chytrid fungus *Batrachochytrium dendrobatidis* (10% of taxa). (Table 3). Twenty-five taxa registered "non-genuine" status changes attributable to improved knowledge of taxonomy or geographic distribution, while 19 taxa maintained the same threat category as listed in the first national assessment (Table 2).

Degree of non-randomness in threats of the species

The family data set showed a significant deviation from a random distribution of threatened species and subspecies among the amphibian families ($\chi^2 = 76.5$, df = 9 $P < 0.001$). Randomization tests showed two families to be significantly overthreatened (Telmatobiidae and Batrachylidae with 100% and 60% of their taxa threatened, respectively) and two families to be significantly underthreatened (Hylidae and Leptodactylidae with 5% and 14% of the taxa threatened, respectively) (Tables 2 and 4).

The ecoregions data set also showed a significant deviation from a random distribution of threatened taxa ($\chi^2 = 140.25$, df = 14 $P < 0.001$). Randomization tests showed four ecoregions overthreatened (Fig. 1): Patagonian Steepe (75% of the taxa threatened); Patagonian Woodlands (65% of the taxa threatened); Puna (71% of the taxa threatened), and Yungas Forests (29% of the taxa threatened) [Table 5].

Discussion

This update shows a substantial improvement in the knowledge of amphibian diversity in Argentina since the first major assessment in 2000, with 11 new species described (see Vaira et al. 2012) and improved knowledge on taxonomy and/or geographic distribution of several species reflected by 16 taxa decreasing their threat categories and changing status as a consequence of the amount of information (i.e., the "non genuine" status change).

Unfortunately, there is also evidence of taxa increasing their threat status in Argentina since the first national conservation assessment. Habitat loss and/or degradation, chytrid fungus infection, and introduction of invasive species have been considered as principal threats suggested for eight species changing to higher threat categories (Vaira et al. 2012). Nonetheless, the lack of studies that simultaneously evaluate the importance of those threats on the species is notable.

Major concerns constitute the lack of registries verification of these four species in the wild for prolonged time lapses: *Telmatobius ceiorum*, *T. laticeps*, *Gastrotheca christiani*, and *G. chrysosticta* (Barrionuevo and Ponssa 2008; Akmentins et al. 2012) even after exhaustive surveys conducted in recent years within their natural geographic ranges. Whether these species are still extant is uncertain. Nevertheless, it is generally recommended to be extremely cautious to declare a species extinct because of the conservation implications involved, and it seems appropriate to encourage additional conservation efforts until there is no reasonable doubt of its extinction (Mace et al. 2008; Akmentins et al. 2012). However, to better reflect the likelihood of these species becoming extinct under prevailing circumstances we suggest that their global conservation status should be reconsidered.

Like in most Neotropical countries, there are major gaps of information on the amphibian species of Argentina including genetic, geographic range size, natural history, and ecology. The status of most of their populations is unknown since there is simply not enough information to estimate or infer a trend. Despite limited information, reported declines and identified threats require quick decisions on prioritizing conservation actions on certain

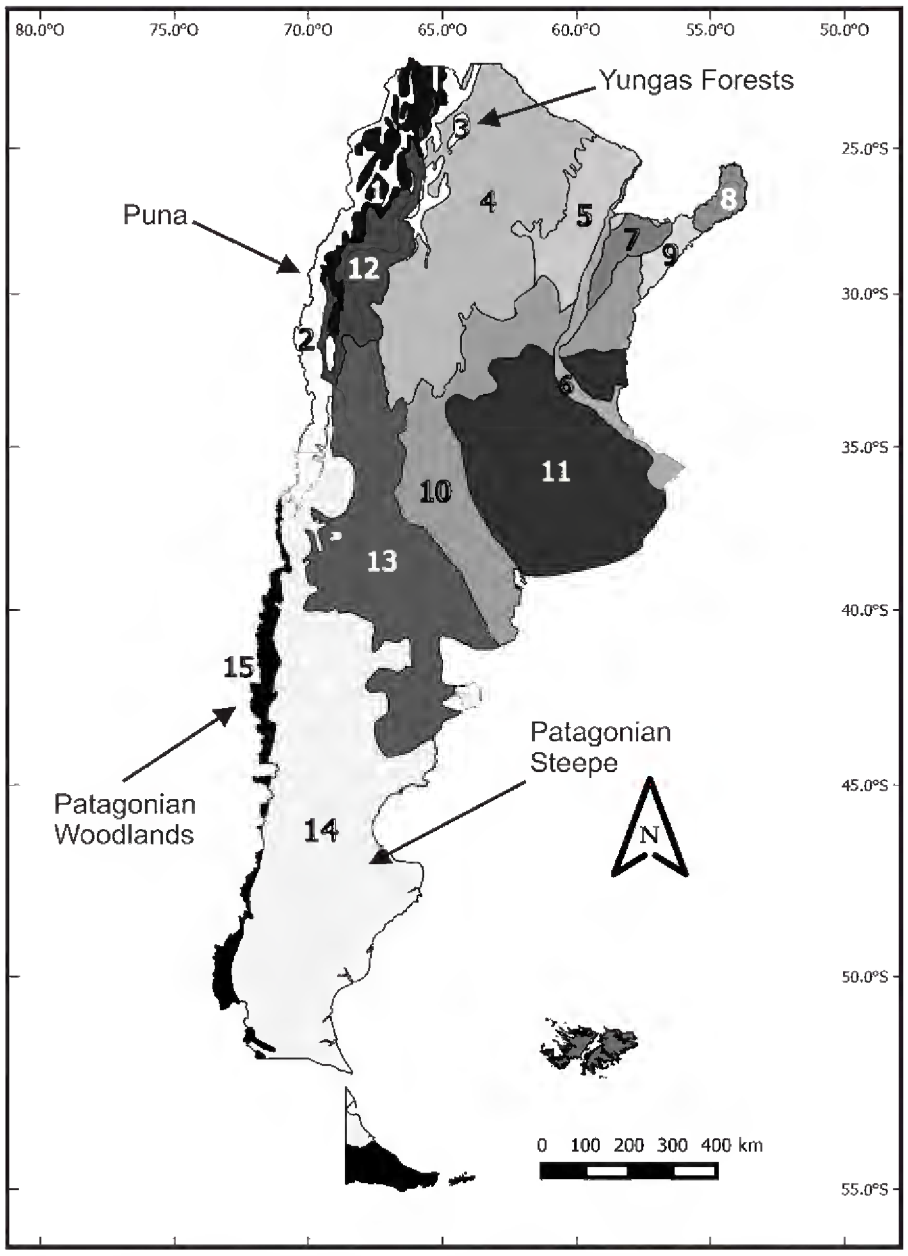

Fig. 1. Map of the ecoregions of Argentina from Burkart et al. 1999. Numbers indicate ecoregions divisions as follows: (1) Puna, (2) High Andean, (3) Yungas Forest, (4) Dry Chaco, (5) Humid Chaco, (6) Delta and Islands of the Parana River, (7) Esteros of Ibera, (8) Paranaen Forest, (9) Campos and Malezales, (10) Espinal, (11) Pampas, (12) Monte of Sierras and Bolsones, (13) Monte de Llanuras and Mesetas, (14) Patagonian Steppe, (15) Patagonian Woodlands. Arrows indicate the four overthreatened ecoregions.

species over others. We encourage the development and implementation of a conservation action plan of threatened amphibian species of Argentina through specialist consensus.

Hylidae and Leptodactylidae were found to be underthreatened families probably because they both contain taxa with large geographic distributions and small numbers of endemic species (Lavilla and Heatwole 2010). Randomization test results suggest that Telmatobiidae and Batrachylidae clades are overthreatened and hence may be especially prone to extinction. Reported threats within these families are consistent with the possibility that shared evolutionary history per se is an important precursor to vulnerability. The genus *Telmatobius* shares ecological traits present in many amphibians that have declined worldwide such as restricted distributions in high mountain ranges, low fecundity, and aquatic adults (Lips et al. 2003; Sodhi et al. 2008; Bielby et al. 2006). Then, endemic populations of *Telmatobius* should be more prone to extinction from environmental and demographic stochasticity which prompts us to consider how severe the human impacts on those species will be. Four possible factors have been suggested as causes of decline for the species of *Telmatobius* in Argentina: unusual climate coupled to an increase in erosive processes and debris flowing events in montane streams, introduction of exotic predatory fishes in the river basins, and chytrid fungus infection (Barrionuevo and Ponsa 2008; Vaira et al. 2012). Similar results were reported in Ecuador, where the most critically endangered species belonging to *Telmatobius* genera occurred in regions characterized by drier conditions and high suitability for *Batrachochytrium dendrobatidis* (Menéndez-Guerrero and Graham 2013).

Species with similar life history traits and habitat use patterns are likely to be more sensitive to environmental instability and are less able to adapt to or recover from environmental or ecological changes (Sodhi et al. 2008). The evaluation of non-randomness of threat status can help to identify groups of related species that face similar suites of human-caused threat and biological susceptibility due to overlapping geographical distributions and shared evolutionary history respectively. This approach can help us to pinpoint needs for emergency action and to alert policymakers and conservation managers. This knowledge could be used to plan future protected areas where threat is concentrated and to guide mitigation measures. *Telmatobius* and *Atelognathus* might be examples of such an approach, setting conservation actions in the specific ecoregions where these genera inhabit (Patagonian Steepe and Woodland, Puna and Yungas Forests) and to manage their specific threats (e.g., introduction of predatory fishes and/or mining) that might yield better results than directing resources towards single species or individual populations.

On the other hand, broadly distributed species represent another challenge for setting conservation priorities if they comprise evolutionary lineages that may be under different levels of threat. An assessment at country level may lead to conflicting results in the threat category of a species complex and the possibility of over or underestimation of their conservation status. It is conceivable that as studies continue, species which we now consider widespread may indeed be local endemics. Additionally, since the effects of threats can be expected to vary spatially, especially in heterogeneous environments, better assessments are needed across ecoregions and thus fully accomplish the conservation assessment of amphibians in Argentina.

Because our knowledge to estimate the risk of extinction of amphibians of Argentina is still rather limited, the identification of most threatened regions may prove useful in cases where available data limit the certainty of the assessment outcomes. Our approach based on the evaluation of non-randomness of threat status may help to identify regions that are at greater risk and to capture the attention of researchers and policymakers. Thus, our rather broad results may be refined for more concerted

Table 2. Comparison of the 2000 and 2012 national assessments of threatened species of Argentina showing number of taxa with the same, increasing, or decreasing threat categories. A status change due to reported increase or decrease of threats was considered a "genuine" change. Those changes attributable to improved knowledge of both geographic distribution and taxonomy of the taxa were considered as "non-genuine" status changes (adapted from Hoffmann et al. 2010).

Families	Threatened species and subspecies on 2000 Red List	Threatened species and subspecies on 2012 Red List	Number taxa same threat category	Number taxa increasing threat categories	Number taxa decreasing threat categories	"Genuine" status change	"Non-genuine" status change
Siphonopidae (3)	2	0	0	0	2	0	2
Typhlonectidae (1)	1	0	0	0	1	0	1
Alsodidae (9)	2	5	1	4	0	4	0
Batrachylidae (15)	11	9	7	1	3	0	4
Brachycephalidae (1)	0	0	0	0	0	0	0
Bufonidae (30)[b]	9[a]	7[a,b]	4	2[a]	2[a]	1[a]	3[a]
Centrolenidae (1)	1	0	0	0	1	0	1
Ceratophryidae (6)	0	1	0	1	0	1	0
Craugastoridae (3)[b,c]	1	2[b]	1	1	0	0	1
Hemiphractidae (3)	3	3	0	3	0	3	0
Hylidae (38)	6	2	2	0	4	0	4
Hylodidae (2)	1	0	0	0	1	0	1
Leptodactylidae (37)	5	5	3	2	0	1	1
Microhylidae (4)[b,c]	0	0	0	0	0	0	0
Odontophrynidae (8)	2	1	1	0	1	0	1
Rhinodermatidae (1)	1	1	0	1	0	1	0
Telmatobiidae (15)	10	15[b]	0	14	1	9	6

Notes: Taxonomy follows Frost (2015). See Vaira et al. (2012) for the complete list of species and subspecies considered (see also text of this contribution to account for a few nomenclatural changes at genera and species level).
[a] The threatened taxa in 2000 and 2012 are not the same. See Vaira et al. (2012).
[b] Include new species described after 2000.
[c] Include one new species described after 2012 and not evaluated.

studies focused on particular regions to expand the assessment goals not only to identify species at risk but also threats to ecological and evolutionary processes.

Conclusion

Applications of the national assessment: Challenges and future directions

Compiling a national threatened species lists helps to reveal information gaps and stimulate data collection focusing on species or areas where there may be needed conservation actions and where more research may be required (Gärdenfors 2001). We have now a substantial body of knowledge that can provide insights on the conservation status of amphibians of Argentina. A remaining task should be to objectively evaluate the uncertainties of the national assessment. The performance of the national assessment may be improved by testing and refining the accuracy of protocols and criteria to ensure future reassessments in an objective, comparable, and repeatable manner. Also, we must foster better linkages between national and global assessment efforts (de Grammont and Cuarón 2006).

Much is still unknown about potential threats in most species of amphibians of Argentina and many groups exhibit high levels of data deficiency doing status assessments unevenly detailed across species (Vaira et al. 2012). Due to the limited number of empirical data for most species, the national assessment can assist in the identification of groups of species that are more prone to future declines under common threats, due to their shared traits and geographic distributions, constituting an alternative approach to integrate this knowledge into the development of coordinated strategies for data collection or into proactive conservation programs. Data of "genuine" changes in the status of threatened species can then be used to measure progress of programs, and also be used to inspire development of national policies and legislation to protect species and particular regions they inhabit.

An exclusive focus on species-based approaches to conservation planning is controversial (Sætersdal and Gjerde 2011; Nicholson et al. 2013). As better data and methodologies become available, defining priority areas for conservation constitute a most desirable goal (Jenkins et al. 2013). Ideally, we must also address the complexity of natural ecosystems including phylogenetic, ecolog-

Table 3. Species of amphibians of Argentina that increase their threat categories between the 2000 and the 2012 national Red List assessment. Only species with "genuine changes" were considered (see text for explanation). Reasons of changes follow Vaira et al. (2012). Values in parentheses indicate status deteriorations from a lower to a higher category of threat.

Species	Threat category in Argentina	Reason of change
Alsodes australis	VU (-1)	invasive species
Alsodes gargola	VU (-1)	habitat deterioration
Alsodes neuquensis	AM (-1)	invasive species
Alsodes pehuenche	EP (-3)	habitat deterioration
Rhinella achalensis	AM (-1)	habitat deterioration / *Bd**
Ceratophrys ornata	VU (-1)	habitat deterioration
Gastrotheca christiani	EP (-2)	population decline
Gastrotheca chrysosticta	EP (-2)	population decline
Gastrotheca gracilis	EP (-2)	population decline
Pleurodema somuncurense	EP (-1)	habitat deterioration
Rhinoderma darwini	AM (-1)	population decline
Telmatobius ceiorum	EP (-2)	population decline
Telmatobius contrerasi	AM (-2)	population decline
Telmatobius hauthali	AM (-1)	population decline
Telmatobius laticeps	EP (-2)	population decline
Telmatobius oxycephalus	AM (-1)	population decline
Telmatobius pisanoi	AM (-1)	population decline / *Bd**
Telmatobius schreiteri	AM (-1)	population decline
Telmatobius scrocchii	VU (-1)	population decline
Telmatobius stephani	AM (-1)	population decline

Categories: Vulnerable (VU), Threatened (AM), Endangered (EP).
* *Bd*: Infection caused by chytrid fungus, *Batrachochytrium dendrobatidis*.

Table 4. Results of the analysis of distribution of threatened species in the amphibian families of Argentina after the omission of Insufficiently Known (IC) species. The null hypothesis (threat status is taxonomically random) was rejected if *P* values were equal or less than 0.025% at either tail. Families under or overthreatened are bolded. NA: families represented by an insufficient number of species from analysis.

Families	Threatened taxa/ Total # of taxa*	>Expected threat-level *P*-value	<Expected threat-level *P*-value
Alsodidae	5/7	0.04	NA
Batrachylidae	9/11	**0.001**	1
Bufonidae	7/25	0.74	0.49
Ceratophryidae	1/6	0.89	NA
Hemiphractidae	3/3	0.03	NA
Hylidae	2/37	1	**<0.001**
Leptodactylidae	5/36	1	**0.01**
Microhylidae	0/3	1	NA
Odontophrynidae	1/7	0.93	NA
Telmatobiidae	15/15	**<0.001**	1

* IC species omitted.

ical, and evolutionary processes (Lindenmayer et al. 2007). National conservation assessment disaggregated by habitats, ecosystems, or ecoregions can thus provide a valuable base to support the design of priority areas requiring us to translate assessments from country to regional or local levels.

A common confusion introduced in some national conservation assessment applications is to consider conservation status and conservation priorities as equals when they are related but different processes. Conservation status alone should not necessarily determine conservation priorities (de Grammont and Cuarón 2006). Assigning species to a threat category in a conservation assessment should be an objectively scientific process to estimate the risk of extinction of a species. By contrast, setting conservation priorities determine which species should be protected and will often involve political as well as logistical considerations, so it is possible to establish different sets of species with conservation priorities in different regions within the country. Both components are essential for better policy-making and for more accurate scenarios for conservation and management.

Many national or regional conservation agencies interpret conservation assessments as a priority-setting tool for conservation action (Miller et al. 2007). Sometimes, there is a direct connection between conservation assessments and conservation policies, basing protective legislation or conservation actions directly on conservation categories. This can have undesired consequences, such as Data Deficient species being disregarded when allocating resources for conservation or protection. We must consider an increased communication and cooperation between researchers and policy-makers for generating and using national conservation assessments to effective conservation actions and legislation.

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Table 5. Results of the analysis of distribution of threatened species in the ecoregions of Argentina after the omission of Insufficiently Known (IC) species. The null hypothesis (threat status is geographically random) was rejected if *P* values were equal or less than 0.025% at either tail. Ecoregions under or overthreatened are bolded. NA: ecoregions represented by an insufficient number of species from analysis.

Ecoregions[1]	Threatened taxa / Total no. of taxa*	>Expected threat-level *P*-value	<Expected threat-level *P*-value
Campos and Malezales	1/41	0.997	0.169
Delta and Islands of the Paraná river	0/42	1	0.037
Dry Chaco	5/54	0.879	0.762
Espinal	2/40	0.978	0.392
Esteros of Iberá	1/44	0.998	0.137
High Andean	2/55	0.143	NA
Humid Chaco	2/51	0.995	0.228
Monte de Sierra and Bolsones	1/11	0.806	NA
Monte of Llanuras and Mesetas	2/9	0.352	NA
Pampan	5/26	0.279	0.986
Paranaean Forest	3/52	0.981	NA
Patagonian Steepe	6/8	**<0.001**	NA
Patagonian Woodlands	11/17	**<0.001**	NA
Puna	10/14	**<0.001**	NA
Yungas Forests	11/38	**0.009**	1

[1]From Lavilla and Heatwole (2010); *IC omitted.

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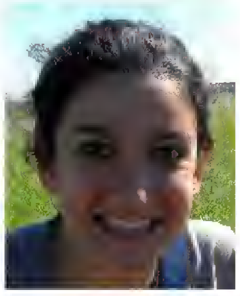

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